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The July 14th 2013 vulcanian explosion at Tungurahua Volcano: Pre-explosive conduit conditions

H.E. Gaunt[1], A. Burgisser[2], P. Mothes[1], P. Meredith[3], J. Browning[4], E. Criollo[5], B. Bernard[1]

[1]nstituto GeofíÌ•sico, Escuela PolitéÌ•cnica Nacional (IG-EPN), Ap. 17-01-2759, Quito, Ecuador

[2]Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, IRD, IFSTTAR, ISTerre, 38000 Grenoble, France

[3]Rock and Ice Physics Laboratory, Department of Earth Science, University College London, London, UK

[4]Department of Mining Engineering and Department of Structural and Geotechnical Engineering, Pontificia Universidad Catolica de Chile

[5]Departamento de Metalurgia Extractiva, Escuela Politécnica Nacional, Quito, Ecuador

The July 14th 2013 Vulcanian explosion at Tungurahua was one of the most powerful explosions not just at this volcano but worldwide; generating some of the highest recorded infrasound energies (> 5000 Pa). The explosion occurred after 2 months of quiescence, with the previous eruptive phase ending in May. Two weeks prior to the July 14th event, seismicity and tilt signals began to steadily increase, indicating the probable intrusion of a new batch of magma. The triggering of such powerful Vulcanian events is generally understood to result from the sudden and violent decompression of the top of an over pressurized magma column due to the rupture of a magmatic plug. The key to understanding these events, and therefore to improving forecasts, is knowing pre-explosive conduit conditions and how and why such large gas over-pressures are able to accumulate.

Textural and petro-physical analysis of eruptive products were used to reconstruct the pre-explosive conditions present in the conduit prior to the onset of the July 14th 2013 Vulcanian event. Feldspar microlite textures and vesicle size distributions were used jointly with a two-step recompression model to create a full picture of the conduit conditions and decompression histories of the erupted samples. The physical and mechanical properties (permeability, tensile strength, texture and micro-structure) of samples of the dense magma cap present in the shallowest part of the conduit were measured to provide information on what makes them so efficient at inhibiting gas loss and promoting gas over-pressurization of the conduit.

Results of the two-step model suggest that the majority of samples were ejected from < 1.5 km depth in the conduit with only 3 samples coming from deeper. The top 50 m of the conduit were occupied by an extremely dense (< 2% porosity) highly crystalline magma plug, with very low permeability (1x10-17 to 1x10-18 m2 at 5 MPa effective pressure) and a relatively high tensile strength (9 to 13 MPa). Directly below this was a high porosity zone (10 to 50%), around 600 m thick with large connected bubbles and that had relatively low crystallinity, beneath which, the magma maintained a standard density profile, with porosity and crystallinity decreasing with depth. Crystal textures revealed relatively slow decompression rates with very few disequilibrium crystal morphologies, probably as a result of long (around 2 month) residence times in the shallow conduit.

Overall, results suggest the following unfolding of events prior to the Vulcanian event. Remnants of magma from the previous eruptive phase in May stalled in the shallow conduit, triggering a burst of crystal nucleation and growth and, coupled with efficient outgassing, this resulted in a dense crystalline plug. Below this plug, closed-system degassing continued and resulted in a high porosity zone with modest over-pressures. The influx of gas from the ascent of new magma most likely contributed more gas pressure into an already gas over pressurized conduit, thereby accelerating the sudden onset of this explosion only shortly after deformation and seismic trends indicated new magma was present in the cone.